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ABSTRACT

The current crisis in the quality and instruction of pre-college mathematics/science education is acknowledged to be one of the major problems confronting American education. Such future demographic changes as increasing numbers of immigrant and minority-group students in the school population will make the crisis more acute. Many factors need to be examined in an attempt to resolve the crisis, in particular those related to the shortage of science/mathematics teachers. These include low starting salaries, teachers being cut off from new disciplinary developments within a few years after entering the classroom, and the low prestige of pre-college science/mathematics teachers within the science community. Since the crisis cannot be "solved," solutions to smaller problems are offered. To increase the flow of highly qualified/enthusiastic science/mathematics teachers, establishment of incentives to encourage and the use of advanced, pedagogically qualified graduate students as part-time teachers in secondary schools is recommended. Hiring scientists/technicians to teach in schools of education is also recommended to help keep mathematics/science instruction and instructors current with changing developments; National Science Foundation-supported summer programs and provision of summer employment opportunities for teachers in university-industry research facilities are also recommended to achieve this goal. (JN)

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ADDRESSING THE CRISIS IN PRECOLLEGIATE MATHEMATICS AND SCIENCE EDUCATION

by

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Briefing for the House of Representatives' Democratic Caucus. The briefing was organized by the Population Resource Center and held on April 27, 1983. This material was drawn from a forthcoming longer paper by the author, Scientists Interested in Education and Educators Interested in Science: Bridging the Gap. The author thanks Ami Zusman for her assistance in the preparation of this statement.

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The current crisis in the quality and instruction of precollegiate mathematics and science education is now acknowledged to be one of the major problems confronting American education -- and, by logical extension, American society in general. Economic, demographic and social changes have created this crisis. As I will discuss shortly, demographic changes will make this crisis even more acute in the future, unless we take steps to alleviate it. My purpose today is to describe this crisis and to argue that we cannot approach it with the simplistic and short-term "solutions" we sought to apply to the similarly perceived crisis in the post-Sputnik era. Money is not enough. Unless policy initiatives deal with underlying problems and draw on the skills and expertise of the scientific and technological community, we likely will find ourselves in 10 to 15 years where we found ourselves 10 to 15 years after Sputnik -- with the problem no closer to resolution.

I. THE PROBLEM

The evidence that a crisis in precollegiate mathematics and science education exists is seemingly incontrovertible:

- A 1981 National Science Teachers Association survey reported that, nationally, over half of newly employed science and mathematics teachers in secondary schools were employed on an emergency basis because no qualified teachers could be found (Guthrie and Zusman, 1982, p. 7).

- Mathematics and science teachers are leaving the teaching profession for jobs in industry at a rate four to five times their rate of replacement

(Wicker, 1983, p. a-21).

- More than 50 percent of the students receiving degrees in 1981, qualifying them to teach mathematics or science in secondary schools, went into industry (Institute for School Development, 1983, p. 9).

- Between 1966 and 1980, the percentage of freshman students planning to major in mathematics and physical science fell from 7.8 percent to 2.6 percent (NSF, 1982, p. 66).

- The percentage of college-bound high school seniors scoring 650 and above on the mathematics portion of the Scholastic Aptitude Test (SAT) declined by 23.4 percent, while the proportion scoring fewer than 300 points increased by 38 percent during the ten-year period 1972-82 (Chronicle of Higher Education, 1983, p. 7).

- Since 1960, enrollment in remedial mathematics courses has increased by 165 percent. Remedial courses now constitute 36 percent of all mathematics enrollments, compared to 13 percent in 1960 (NSF, 1982, p. 77).

- The absolute disparity in scores on the mathematics portion of the SAT for college-bound seniors planning to major in education and seniors planning majors in all disciplines increased by 50 percent between 1973 and 1981. In 1973 the average mathematics SAT score for all majors was 481; for prospective education majors, it was 449. In 1981, the scores were 467 and 419 respectively -- a difference of 48 points (NSF, 1982, p. 125).

- Universities are relying increasingly on foreign students to provide new Ph.Ds in engineering, computer science, mathematics and the physical sciences. According to the National Research Council, in 1981 more than 51.5 percent of the new Ph.Ds in engineering were foreign students. The numbers for computer science, mathematics and the physical sciences were 25.6, 32.3 and 22.0 percent respectively (Chronicle of Higher Education, 1982, p. 8).

Future demographic changes will make this crisis even more acute. Three trends in particular have implications for mathematics and science education. First, school enrollments, which for

over a decade have been declining, will begin rising again starting in fall 1983, as the children of the baby boom generation enter school. By the end of this decade, larger numbers of high school students will be ready to take mathematics and science courses (Guthrie and Zusman, 1982, p. 4).

Second, even while school enrollments climb, the traditional pool for school teachers will continue to shrink. This is the result of several factors. The number of persons turning 22 years old (the typical age for entering teaching) will begin to decline about 4 percent annually starting in 1986 (Morrison, 1976, p. 20). The reserve pool of teachers we once could count on -- mostly women prepared to reenter the labor market after several years' absence -- will contract because relatively few college graduates with teacher preparation training are now entering this reserve. And, most importantly, expanding career opportunities for women and minorities mean that we no longer can -- nor should -- rely on discriminatory practices to bring a disproportionately high number of women and minorities into the teaching profession. The decline in the overall teaching pool is likely to be exacerbated in mathematics and science fields, for the reasons I have discussed.

Third, immigrant and minority-group students, many of whom in the past have taken fewer mathematics and science courses than other students, will comprise an increasing proportion of our school-age population. Unless we develop new approaches to stimulate interest in mathematics and science fields by these

students as well as by women, who also have entered mathematics and science fields in disproportionately small numbers, the nation may be unable to achieve its fullest scientific and technological potential.

If the trends of declining student interest in mathematics and science, plunging scores on achievement examinations, and a diminishing supply of qualified precollegiate mathematics and science teachers continue or worsen, the United States shortly may find its ability to maintain its leadership in science and technology irreversibly compromised. The consequences would be disastrous not only for the nation's future economic performance but for its social, political and intellectual fabric as well. Advanced training in mathematics and science is central to the growth of high-technology industry and businesses, seen by many as the most promising economic sector for the U.S. at a time when the old low-technology industries in steel, automobiles and the like are experiencing high unemployment rates. Advanced technology is critical to maintaining the increasingly sophisticated apparatus needed for national security. Conversely, inadequate math and science education limits the economic advancement and career opportunities of individuals, a factor which has widened the economic gap between minority and non-minority, female and male; and it lowers the economic productivity of the nation as a whole. Analysts have argued that the decline in the quality of science and mathematics instruction has already impaired the ability of the citizenry to exercise informed judgment about issues requiring basic scientific literacy, weakened the nation's

capacity to prepare its youth for life in a technology-intensive future, and threatened U.S. businesses' competitive edge over countries such as West Germany and Japan, where high importance is placed on mathematics and science education (White, 1982, p. 11).

II. THE SUPPLY-SIDE SOLUTION: PROBLEM AND PROSPECTS

Would-be educational reformers have offered a number of suggestions to deal with the crisis in precollegiate mathematics and science education. One frequent proposal is to make massive public investments in the production of more and better prepared mathematics and science teachers. The most often suggested investments are tuition scholarships for prospective classroom recruits and incentives for colleges and universities to improve their programs in mathematics and science education for prospective teachers. Suggested solutions, not unlike those applied during the post-Sputnik period of reform, also include subsidized loans for prospective teachers and re-training grants for uncertified mathematics and science teachers willing to upgrade their skills.

Though essential, these initiatives will not be sufficient. First, any strategy which focuses solely on perspective classroom teachers and not on the teachers now in the classroom will have no appreciable effect for several years. Second, the shortage of qualified and competent mathematics and science teachers is due

to a set of factors which will remain unaffected by supply-side solutions. The most important of these factors are the following:

1. The abysmally low starting salaries of prospective mathematics and science teachers, compared to salaries they would command in industry. This problem, which has decreased the attractiveness of the education profession in all subject areas, produces particularly perverse results in the case of qualified potential science and mathematics teachers. The more qualified the prospective teacher, the greater is that teacher's potential for nurturing the talents of the young. The larger the classroom-industry gap, however, the lower the probability that the critically-needed prospective teacher will end up in the classroom. In other words, the well-qualified would-be teacher, who is potentially capable of doing the greatest good for the greatest number, is being asked to make the greatest financial sacrifice. Is it any wonder that not only are the brightest students shunning careers in mathematics and science education, but the most academically able teachers are leaving the profession in disproportionate numbers? (Toch, 1982, p. 14.)

2. The prospect every beginning science or mathematics teacher faces, of being cut off from new disciplinary developments and breakthroughs within a few years after entering classroom service. The struggle the ordinary classroom teacher engages in to make science and mathematics accessible to students leaves little time for advanced study or laboratory work. Moreover, the teacher who prevails against the odds and continues to

improve his or her understanding of the subject area will rarely be given an opportunity to use this new knowledge in the classroom, because most science and mathematics teaching is directed at students studying "basic" science and "elementary" mathematics. The sharp decline in the number of high school students taking advanced placement courses in science and mathematics has made this problem even more acute over the last decade.

The teachers who are most likely to be bothered by the specter of intellectual obsolescence and isolation from the world of the practicing mathematician and scientist are also those most likely to abandon the classroom for employment opportunities which permit them to practice science, or to put their scientific and analytical training to more remunerative uses.

3. <u>The low prestige of precollegiate science and mathematics teachers within the science community</u>. In spite of the long-existing classroom-industry salary gap, many highly qualified prospective or practicing teachers who have left the school system had earlier been willing to -- and some did -- forego income in exchange for the opportunity to serve in the classroom. What, then, altered the early preferences of those who forsook the classroom for industry? There may be several reasons, including the expansion of job opportunities outside education for women and minorities, a growth in technology-oriented business generally, and a real or perceived decline in the working conditions in the schools. However, I believe that a large part of the reason for this classroom exodus is that the psychic benefits

and satisfactions which prospective and practicing mathematics and science teachers derive from classroom service often diminish with time.

The problem of psychic depletion is compounded by the relatively low standing of precollegiate teachers of mathematics and science within the larger scientific community and the constant barrage of criticism directed at them by members of the scientific community, policy makers and others. Except in unusual cases, university-based professors, who think of themselves as "scientists interested in education", rarely come into respectful contact with classroom teachers who, in generous moments, are described as "educators interested in science". When professors do communicate with their classroom counterparts, they usually do so to complain about the sorry state of mathematics and science education in the lower schools.

Faced with a steady cascade of criticism, it is hardly surprising that the classroom teacher turns away from professional organizations dominated by practicing scientists. This only further compounds the feeling of the professoriate that classroom teachers are not serious about science and thus are not to be taken seriously as significant links in the chain of scientific discovery and development.

Let us examine the policy recommendations that have been offered to alleviate the deleterious impact of the salary gap,

the isolation of teachers from the practice of science, and low status within the scientific community.

Two suggestions for solving the salary gap problem have been offered: the first is across-the-board increases in teacher salaries, and the second is salary differentials for mathematics and science teachers. Unfortunately, the chance of either of these alternatives being implemented in the near future is slim. Thus, the chances of ever finding out just how important salaries are in influencing the personal incentive calculus of "would-be" and "used-to-be" teachers are just as slim. Given the current national economic climate, across-the-board salary increases for all teachers, sufficiently large to channel perspective mathematics and science teachers into the classroom and to retain the best and brightest already in the classroom, would be prohibitively expensive. Differential salary schedules for mathematics and science teachers, while less costly, have been vigorously opposed by teachers' unions and professional teachers' associations representing other disciplinary interests. And not without just cause. The relationship between supply and significance is not at all obvious.

The problem of intellectual obsolescence, alienation and isolation is, in theory, easier to solve than the salary-gap problem. Initiatives that would reduce the magnitude of the former mirror those applied during the post-Sputnik period of reform. They include:

- Re-establishing the summer mathematics and science institutes financed by the National Science Foundation (NSF) at the level that existed during the mid-sixties. These institutes should be organized and staffed by scientists and mathematicians as well as educators. They should concentrate their efforts on subject matter material, curriculum experimentation, improvement of pedagogical skills, and technology-assisted instruction.

- Providing summer employment opportunities for selected mathematics and science teachers, in research universities, national laboratories and research laboratories in private industry. The federal government can directly influence the behavior of universities and national laboratories by utilizing a variety of incentives, including partial salary subsidies for such employment. In the case of private industry, tax credits equal to, say, 25 percent of actual salary expenditures should produce an ample supply of employment-training opportunities for qualified classroom teachers.

- "Encouraging" school districts to support talented mathematics and science teachers willing to invest extra time and energy repairing or constructing needed equipment, preparing special demonstration exhibits, or acquiring new skills, such as using computers to teach problem-solving skills. This support could take a number of forms, including released time, extra sabbatical credit, mini-grants for special projects, or fellowships to support further study.

These initiatives carry certain risks. Some of these efforts, for example, may only increase the level of dissatisfaction and discomfort by exposing talented and highly competent teachers to the opportunities that would be theirs if only they would abandon the classroom. Others may even raise the potentially divisive issue of unfair preferential treatment of one class of teachers over teachers in less favored subject areas. However, it is difficult to imagine that the consequences of implementing these modest reforms would be worse than the inevitable consequences of doing nothing.

The low status of precollegiate teachers of mathematics and science within the scientific community may be as formidable a problem to resolve as the classroom-industry salary gap. Some steps that could be taken to alleviate this problem include:

- Inviting mathematics and science teachers to play a more active role in professional scientific organizations.
- Fostering closer relationships between professors in science and mathematics departments and professors in departments of education charged with the task of preparing precollegiate teachers of mathematics and science.
- Encouraging professional scientific organizations to play an active role in establishing standards for precollegiate mathematics and science teachers, developing curriculum, and monitoring and evaluating instructional objectives and performance.
- Last, but not least, the professoriate and other members of the scientific elite should meet the needs that exist among mathematics and science teachers for recognition and reward by acknowledging the contributions of classroom teachers through well-publicized awards ceremonies for outstanding service and performance.

The real questions to be answered are these: 1) "Will implementation of the supply-side solution (for example, through tuition scholarships or re-training) arrest and reverse the ominous trends in precollegiate mathematics and science education?" 2) "Will reforms intended to deal with the problems of low starting salaries, intellectual isolation, psychic depletion and low prestige work?" I am not convinced that they will. Supply-side policy initiatives are unlikely to be sufficient, given the factors inhibiting teacher supply. And reforms extensive enough to overcome these barriers may be too costly to implement or may require fundamental alterations in existing relationships

unlikely to be obtained (i.e., reordering the relationship between precollegiate teachers and university professors, prestige sharing).

III. RECOMMENDATIONS FOR POLICY INITIATIVES

We cannot "solve" the crisis in mathematics and science education. However, we may be able to provide some solutions to smaller problems, aspects of this crisis that are under our control. Moreover, even these problems will not be solved without the significant involvement of the university scientific community. Nevertheless, permit me to offer a few potentially resolvable problems and those solutions to which the federal government can contribute. I will first describe a solution which, while radical, should have an immediate and substantial impact on the shortage of qualified mathematics and science instructors in the classroom. Because its impact would be felt almost immediately -- not more than a year after steps to implement it were first taken -- I will describe this solution in some detail. Then I will sketch more briefly other solutions to aspects of the crisis which should also be implemented -- solutions likely to have a moderate impact in the mid-term or those which could eventually have substantial impact but which are long-range solutions.

Problem: <u>To increase the flow of highly qualified and enthusiastic mathematics and science teachers into the nation's classrooms</u>.

Solution: <u>Establish incentives to encourage and support advanced pedagogically qualified graduate</u>

students in mathematics, science and technology to take on part-time teaching assignments, especially at the junior high and secondary school level. The federal government can contribute to such programs by providing supplemental funding and legitimacy for them.

The average junior high and secondary school teacher of mathematics or science instructs students for 25 forty-five-minute periods per week. A full-time-equivalent teacher can quite easily be obtained by combining the services of three graduate students, whom we will call Graduate Student Instructors (GSIs), each of whom would teach an average of slightly more than 8 forty-five-minute periods per week.

School districts would pay most of the costs for GSIs by utilizing funds currently being used to pay the salaries of unqualified teachers of mathematics and science. However, school districts should not shoulder the entire financial costs associated with the employment of Graduate Student Instructors.

The federal government could assist the development and expansion of GSI programs by awarding supplementary funding to the GSI's department for performing an extraordinary public service. Not only would such funding increase the likelihood that graduate departments would participate in such programs, it would also increase the legitimacy of joint school-university responsibility for precollegiate mathematics and science education and would provide greater visibility for the GSI concept. The

National Science Foundation unit charged with designing programs to improve the quality of precollegiate mathematics and science instruction would be a logical agency to administer such federal funds.

These federal funds might be provided on condition that the university graduate departments, which would benefit from the GSI program by obtaining financial support as well as training for their students, pay some share of the GSI's stipend. Requiring graduate departments to pay part of the GSI's stipend would help guarantee that the potential GSI's graduate advisers and graduate departments will treat precollegiate teaching as a "legitimate" graduate student activity. Graduate advisers and departments would have to exercise some judgement in allocating their resources, an exercise which is bound to produce better decision-making. Where departments now require their graduate students to serve a period of time as teaching assistants in the university, teaching mathematics and science in the high school should be a fully accepted alternative.

The impact of the GSI concept on helping to alleviate the mathematics and science teacher shortage will not be trivial. For example, in 1982, the University of California, Berkeley, had only five individuals in training as science teachers and only one student preparing to be a secondary school mathematics teacher (Guthrie and Zusman, 1982, p. 1). If less than one percent of Berkeley's roughly 4,000 graduate students in mathematics, science and technology were to take part in the GSI

program, the increase in Berkeley's contributions to precollegiate mathematics and science education would be marked.

Problem: To keep mathematics and science instruction and instructors current with changing developments in the field.

Solution (1): Provide federal funding to university schools of education to enable them to employ scientific and technical personnel from private industry on a part-time or short-term basis. Such industry personnel would instruct teacher-credential candidates in the areas of their specialization and would collaborate with education professors and researchers on the development of new instructional devices and software.

The rapid developments occurring in science and technology could be made more accessible to precollegiate teachers if teachers and prospective teachers were brought into close contact with those working in these changing fields. The expertise of industry workers is a resource too little tapped below the college level. Some have suggested employing industry employees in high schools themselves -- a suggestion with merit. However, by bringing industry experts into teacher-training programs, schools of education could produce a multiplier effect, spreading current information and new technology well beyond the confines of a single high school classroom. The amounts of federal funds needed for this effort would be relatively small; some of the costs should also be borne by industry, which should be persuaded that it is in its long-term interest to provide employee release time or other assistance.

Schools of education could also bring together technical experts from industries with the potential to have a large impact

on instruction -- especially from the computer industry as well as from manufacturers of video disks and the like -- and university educators and researchers. Too often those with expertise in student learning processes and those with familiarity with the developing technological tools which could be applied to aid student learning have little interaction. Currently, for example, computer-aided instruction programs rarely go beyond routine drills and introduction to a subject matter. A second problem is money: the costs of designing and developing technologically-based instructional programs or devices are likely to be beyond the budgets of most schools of education. Through collaboration between technical experts from industry and educational researchers in universities, it is likely that far more sophisticated use of the new technology, geared toward real educational needs, could be developed.

Solution (2): Support other programs and means (noted earlier) to reduce current teachers' intellectual isolation. These include NSF-sponsored summer mathematics and science institutes, tax credits to industry and subsidies to universities for providing summer jobs to teachers, and funds to school districts to increase incentives for teachers to upgrade their skills or develop new curricula.

As discussed earlier, these steps carry risks; and, by themselves, they are insufficient to overcome the problem of teacher isolation and obsolescence. Nevertheless, if they can be linked to a significant willingness by the scientific community to interact seriously with classroom teachers, they may help alleviate the problem.

Problem: To reduce the shortage of qualified scientific and technical workers at all levels, while ameliorating the effects of technological displacement.

Solution: Establish an Educational Training Fund, along the lines of the Unemployment Compensation Fund, targeted to employees in technology-sensitive industries.

This final recommendation is radical, long-term and comprehensive. It goes beyond the previously described concerns for precollegiate mathematics and science education. It will not be easy to implement. Nevertheless, it has a large potential for helping shift workers from areas with declining production to those with growing demand. Under this proposal, employers in industries sensitive to technological change would contribute money equal to a small percentage of an employee's salary to a special fund to be used only for training. The longer an employee worked, the more money would accumulate in the special fund. Employees would be eligible to use the money in the fund to offset tuition or related costs for new educational training. The fund would benefit employers as well as employees by encouraging empoyees to keep abreast of technological developments. Although programs would have to be certified as eligible, training should be broadly defined, and individuals should be able to choose both in what the training would be and where it would be given.

This proposal raises a number of questions which would have to be answered. How can we make training programs more attractive to adults than other somewhat related efforts have been, such as those in Europe to give working adults preference in university admissions? Should individuals in certified

training programs also receive unemployment until after their training is completed? How does one improve the chances that the new training will meet employment needs, without narrowly constraining the individual's choices?

I hope this examination of the condition of precollegiate mathematics and science education, its implications for the rest of our society and economy, and some solutions to some aspects of the crisis will open up further discussion of the issues.

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